

Simulating extreme precipitation in the US in the E3SM: Investigating the importance of representing convective intensity versus dynamic structure

PI: Gabriel J. Kooperman (UGA)

Co-I: Kevin A. Reed (SBU)

Co-I: Walter M. Hannah (LLNL)

Co-I: Angeline G. Pendergrass (NCAR/Cornell)

Postdoc: Akintomide A. Akinsanola (UGA)

DOE PI Meeting 2020

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UNIVERSITY OF
GEORGIA



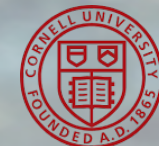
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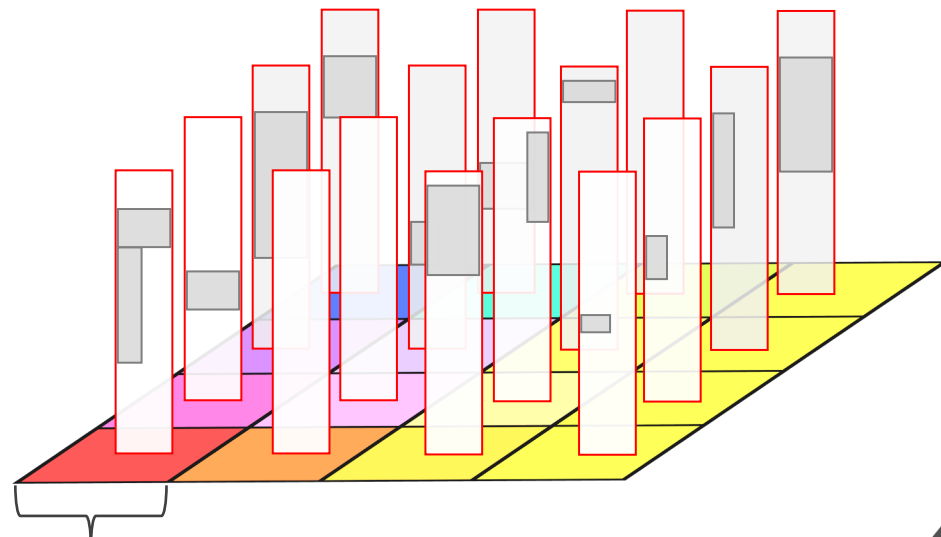
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Cornell University

Investigating the simulation of extreme rain across a range of scales in two promising directions in the development of E3SM

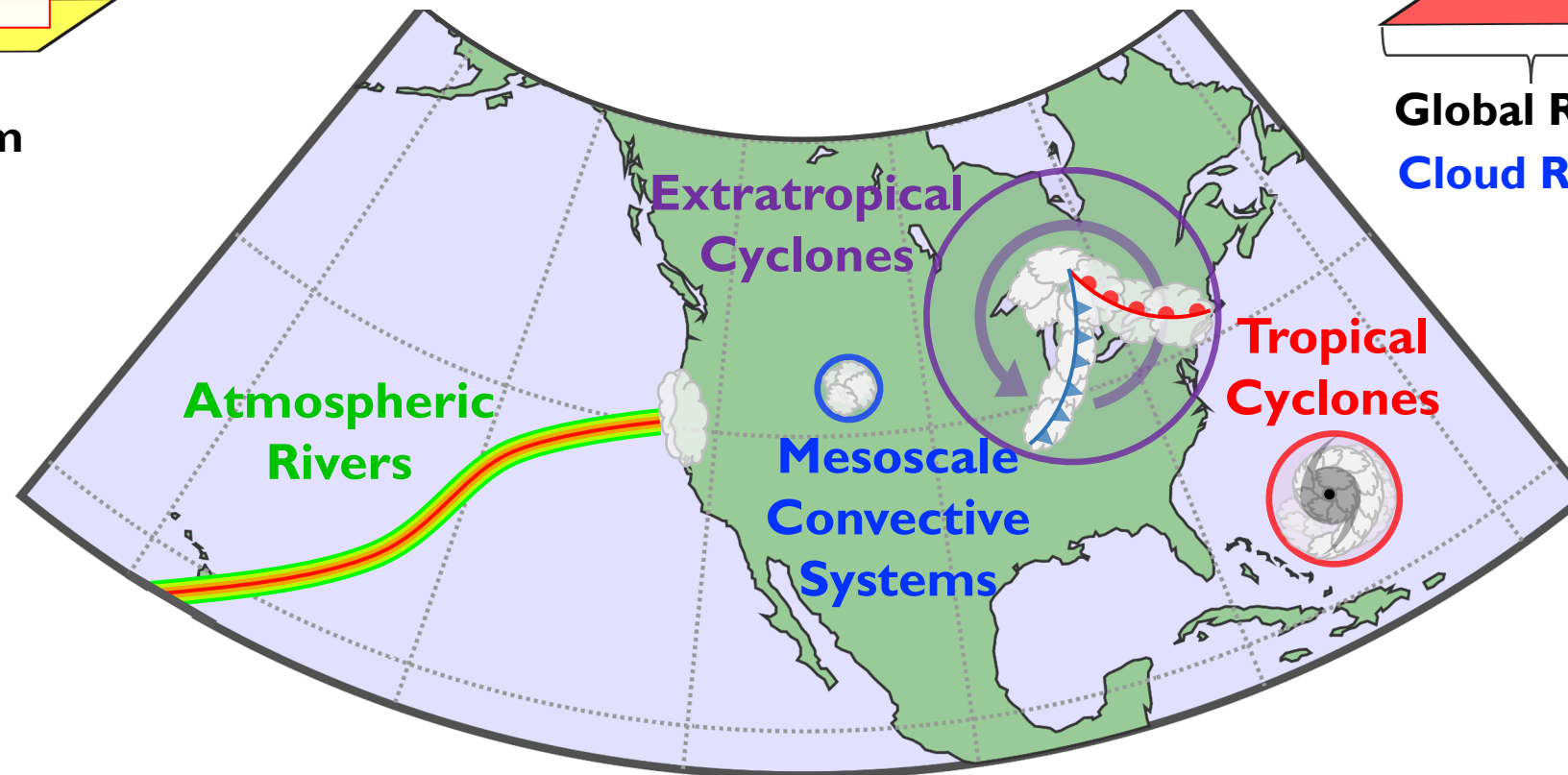
High-Resolution E3SM



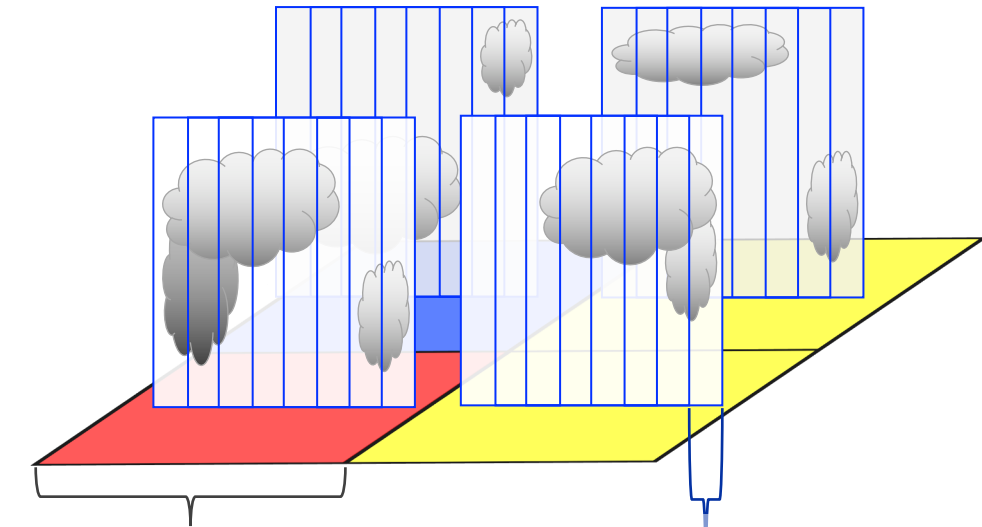
Global Resolution: ~25 km

- **HR-E3SM** captures dynamic structure of storms

Extreme Precipitation Events in the US



Superparameterized E3SM



Global Resolution: ~100 km

Cloud Resolving Model Resolution: 2 km

- **SP-E3SM** captures convective intensity of storms

Investigate tradeoffs between resolving convective processes that control intensity vs. large-scale processes that control the dynamic structure of extreme precipitation events in the US

Major Scientific Research Questions:

- 1. How well does the conventional 100 km resolution E3SM represent extreme precipitation over the US in comparison to other E3SM versions and CMIP6? Which seasons and storm types contribute to biases, and what are their signatures in climatological statistics?**
- 2. For which storms does explicit resolution of the interactions at convective-scales (SP) vs. intermediate-scale dynamics (HR) provide a more realistic simulation of extreme rainfall? Which interactions across small- and large-scale processes (e.g., orographic circulations, convective organization, etc.) are better represented by each approach through the year?**
- 3. Given an equivalent demand on computational resources, which method provides a more realistic overall representation and prediction of extreme precipitation events in the US?**

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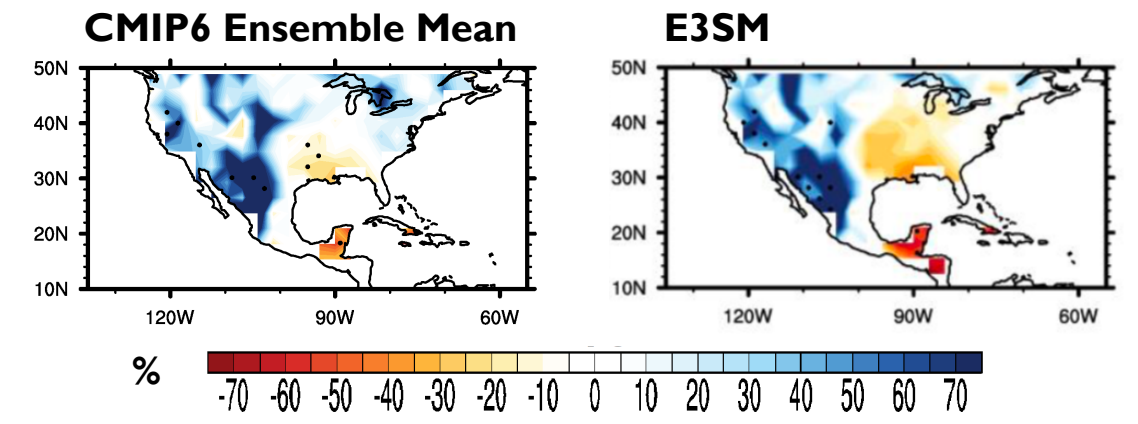
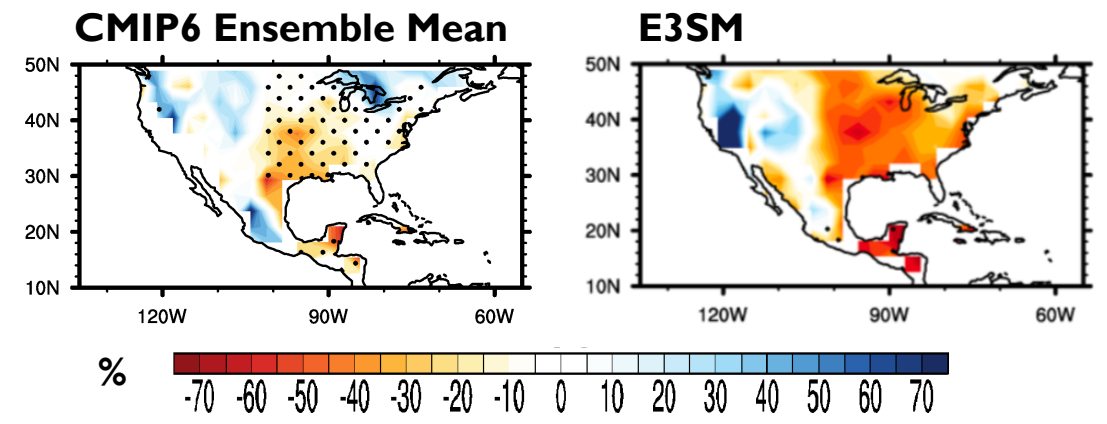
Seasonal representation and projected changes in indices of extreme precipitation over US in CMIP6 and E3SM simulations

Total Rainfall Greater Than 95th Percentile

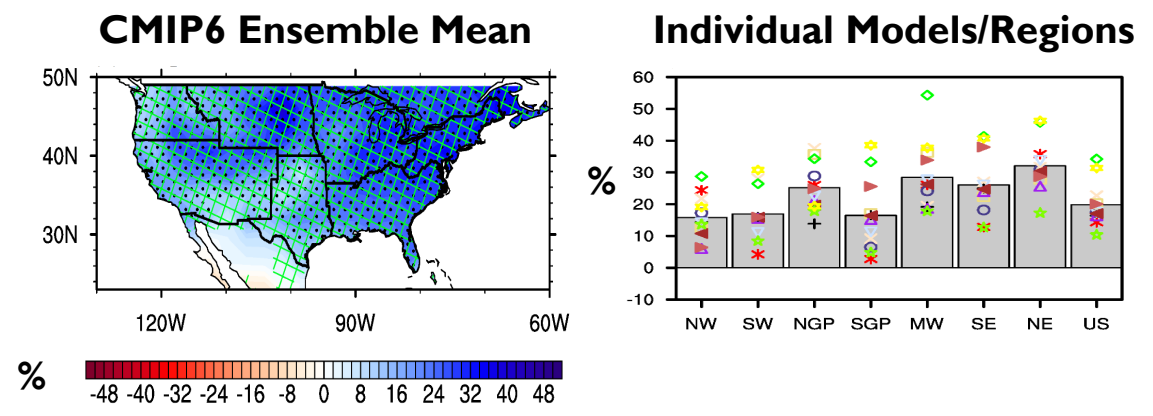
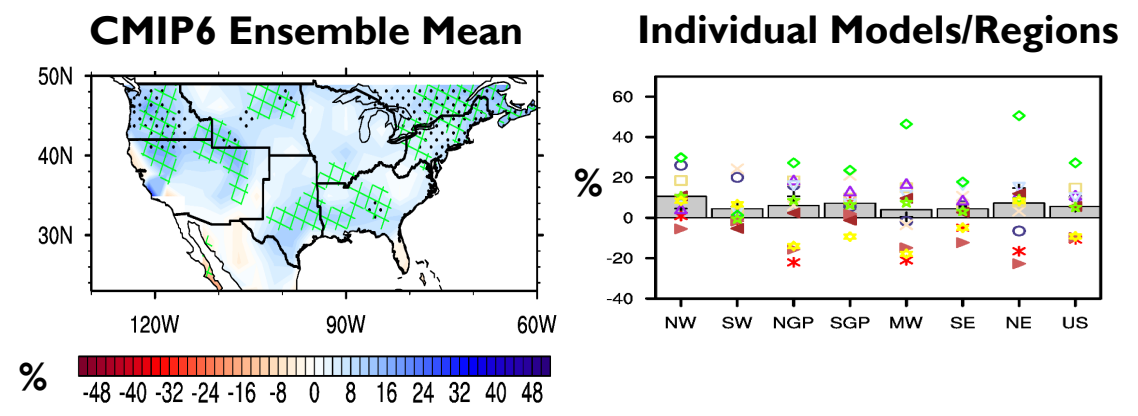
Summer (JJA)

Winter (DJF)

Historical Bias
Relative to CPC



Future Projection
From SSP5-85



Akinsanola, A. A., G. J. Kooperman, K. A. Reed, A. G. Pendergrass, and W. M. Hannah (2020), Projected changes in seasonal precipitation extremes over the United States in CMIP6 simulations, *Environ. Res. Lett.*, doi:10.1088/1748-9326/abb397.

Akinsanola, A. A., G. J. Kooperman, A. G. Pendergrass, W. M. Hannah, and K. A. Reed (2020), Seasonal representation of extreme precipitation indices over the United States in CMIP6 present-day simulations, *Environ. Res. Lett.*, 15(9), doi:10.1088/1748-9326/ab92c1.

Models:

Historical: 16 model ensemble
Projection: 12 model ensemble

Observations:

CPC Daily, GPCP 1DD, TRMM 3B42

Extreme Precipitation Indices:

CDD: Maximum consecutive dry days
CWD: Maximum consecutive wet days
R10mm: Total from heavy precipitation
R20mm: Total from heavier precipitation
PRCPTOT: Total wet-day precipitation

R95pTOT: Total from rates > 95p
R99pTOT: Total from rates > 99p
RX5DAY: Max consecutive 5-day rainfall
SDII: Simple daily intensity
ETCCDI, Tank et al. (2009)

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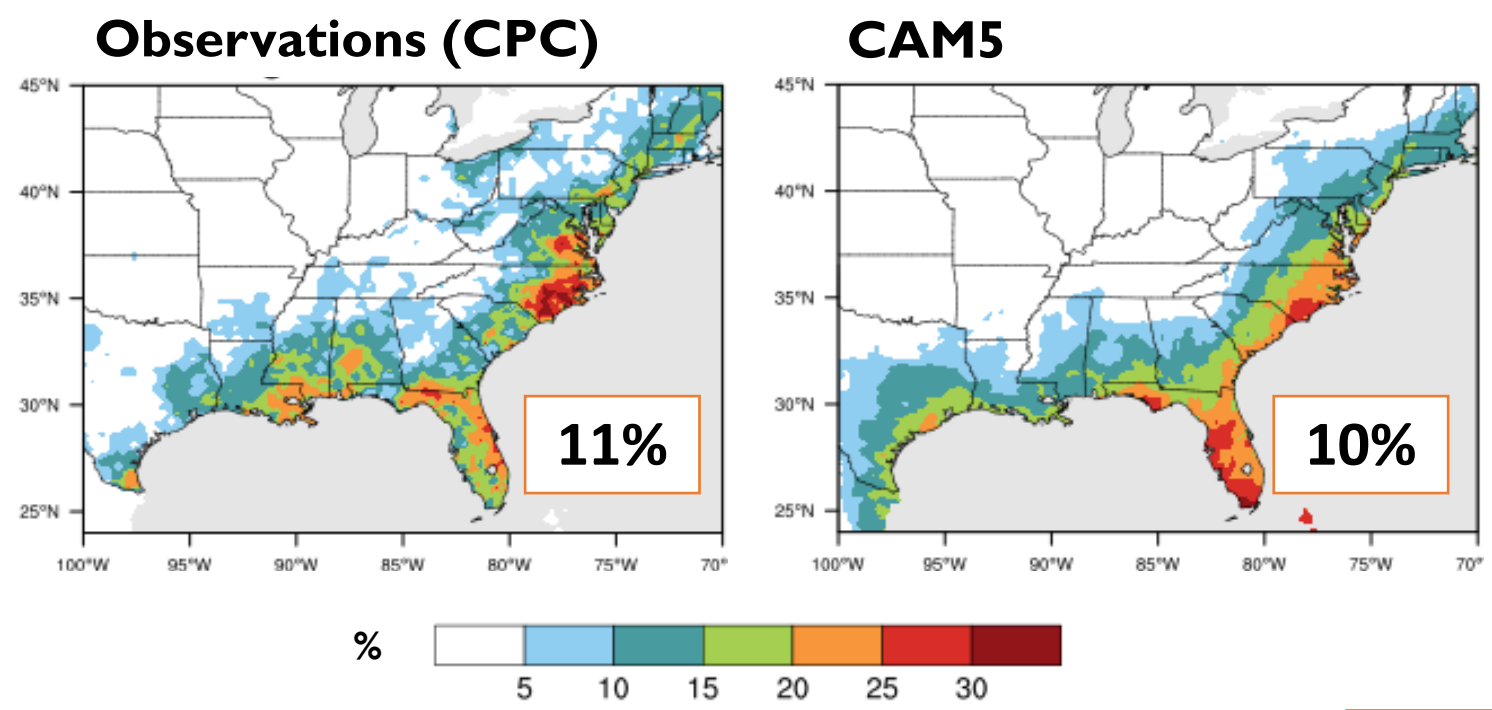
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Using hindcast simulations and feature tracking tools to target specific events and extract the statistics of extreme storms

- TempestExtremes enables efficient identification and extraction of the statistics for extreme precipitation:
- Hindcasts target extreme precipitation producing storms that impact the US, allowing for detailed analysis:

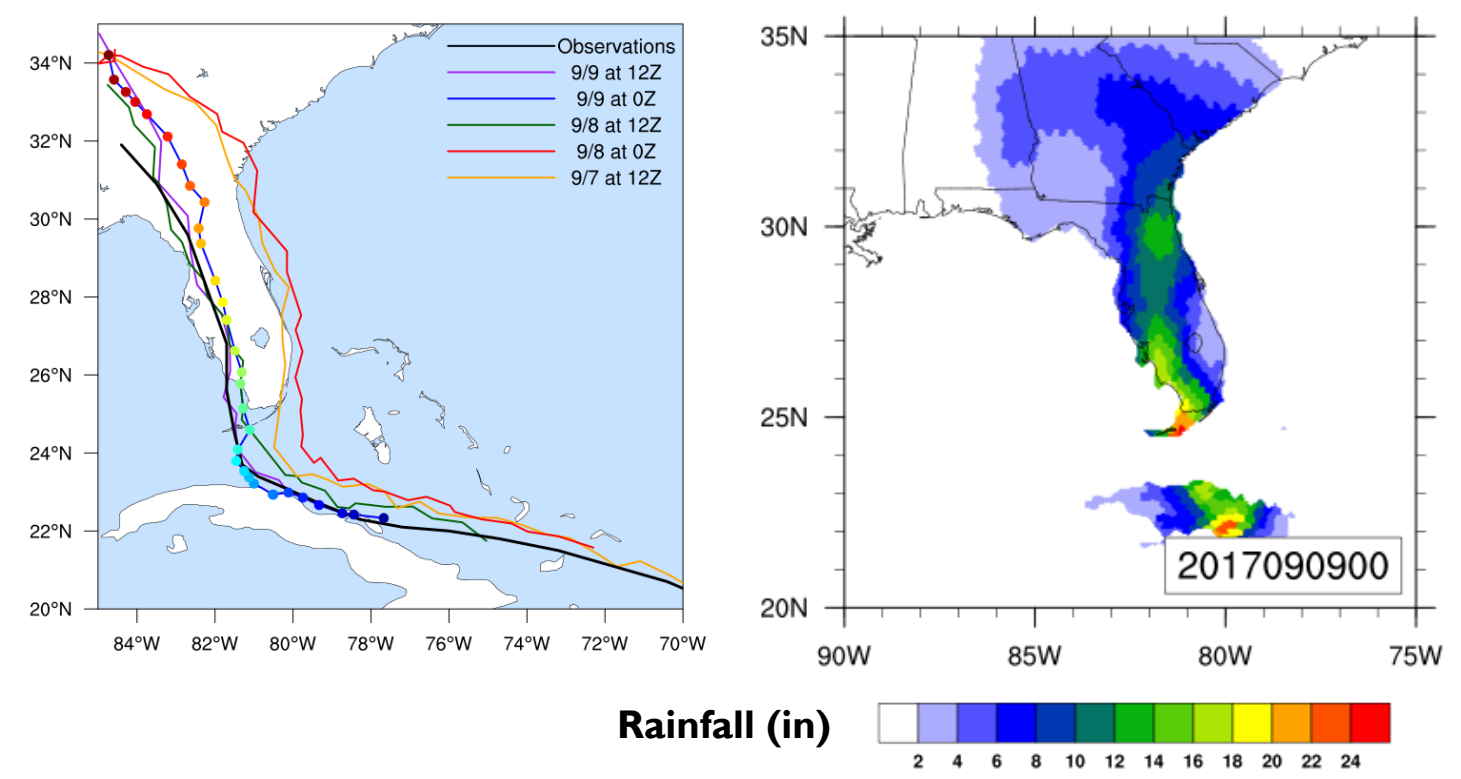
Percent of Extreme Rainfall Events from TCs in AMIP Simulations



Stansfield, A. M., K. A. **Reed**, C. M. Zarzycki, P. A. Ullrich and D. R. Chavas (2020), Assessing Tropical Cyclones' Contribution to Precipitation over the Eastern United States and Sensitivity to the Variable-Resolution Domain Extent, *J. Hydrometeor.*, 21, 1425–1445, doi: 10.1175/JHM-D-19-0240.1.

Co-I Kevin Reed discussed this in Breakout Session 1.3 yesterday (see slides)!

Hindcasts of Hurricane Irma



Similar to: **Reed**, K. A., A. M. Stansfield, M. F. Wehner, and C. M. Zarzycki (2020), Forecasted attribution of the human influence on Hurricane Florence, *Science Advances*, 6(1), doi: 10.1126/sciadv.aaw9253.

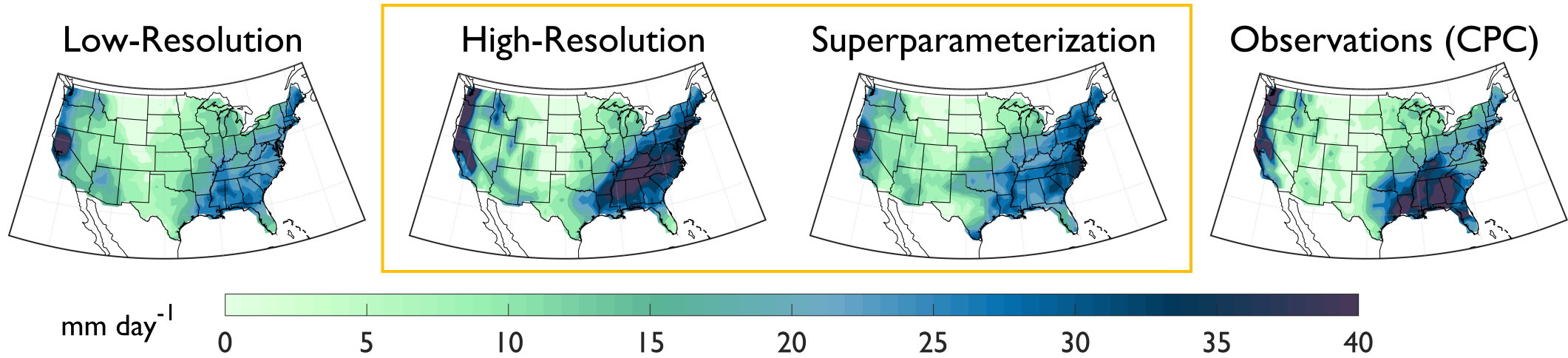
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Early look: Improved intensity from HR-E3SM during Winter and improved intensity and timing in SP-E3SM during Summer

Winter (DJFM) 98th Percentile Daily Precipitation Rate

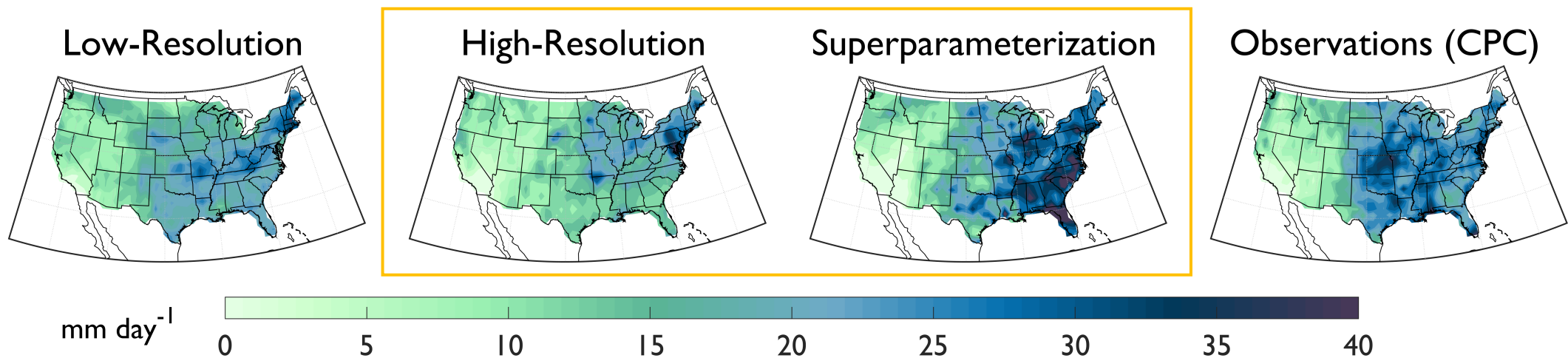


- The ECP project with Co-I Walter Hannah have overcome development challenges (e.g., coupling CRM with SE dynamical core) to enable SP-E3SM.

Other ECP Developments:

- CRM has been ported to C++ to run on Summit GPUs, enabling a deeper look into using high-res CRMs and 3D domains.
- A new CRM is being developed with superior numerics, an ability to run on GPUs or CPUs, and new physics (P3+SHOC).

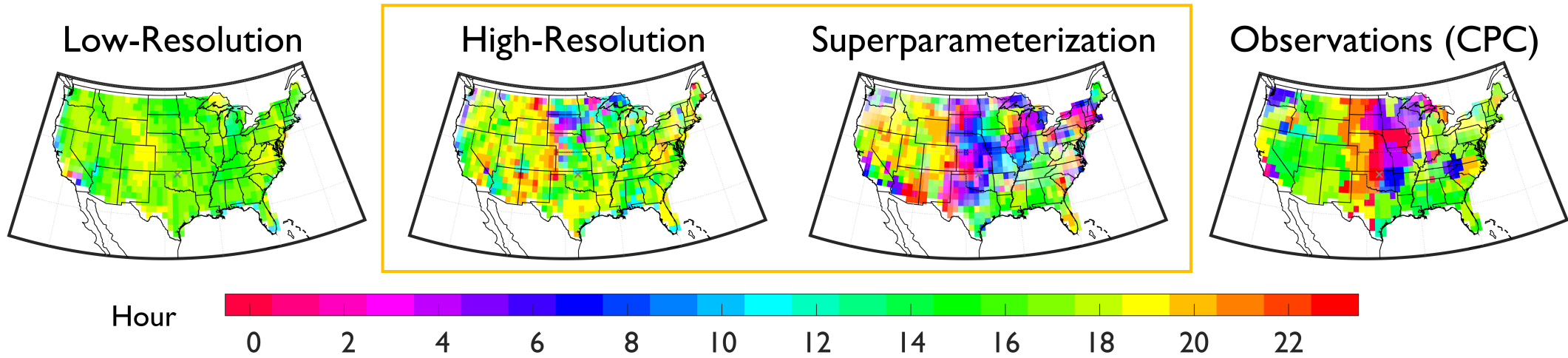
Summer (MJJ) 98th Percentile Daily Precipitation Rate



HR-E3SM and SP-E3SM are configured with equivalent computational expense.

Early look: Improved intensity from HR-E3SM during Winter and improved intensity and timing in SP-E3SM during Summer

Summer (MJJJA) Precipitation Diurnal Maxima

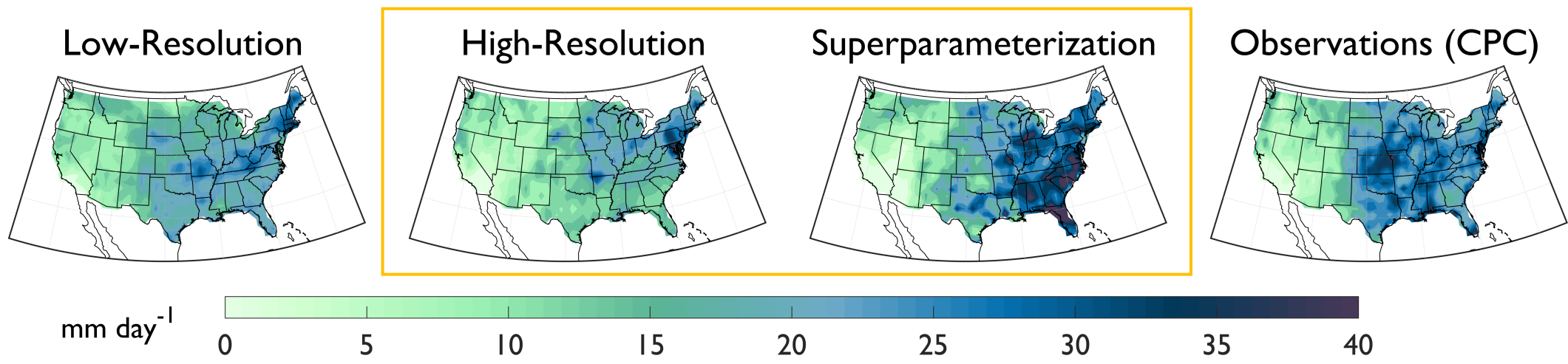


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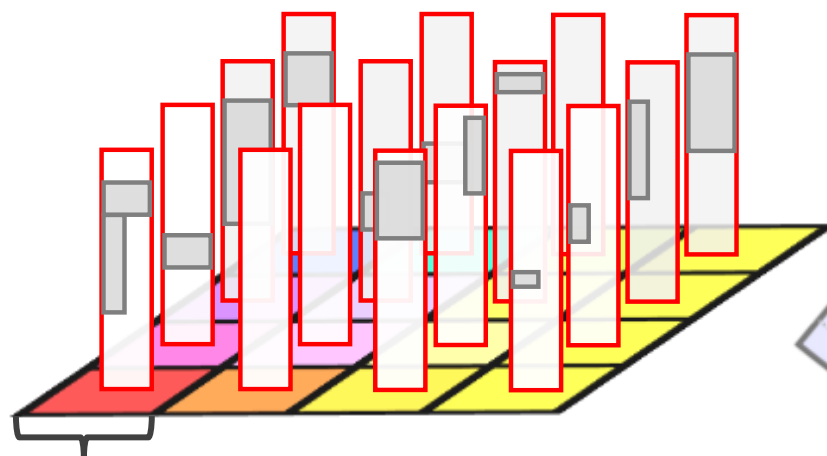
Thank You!

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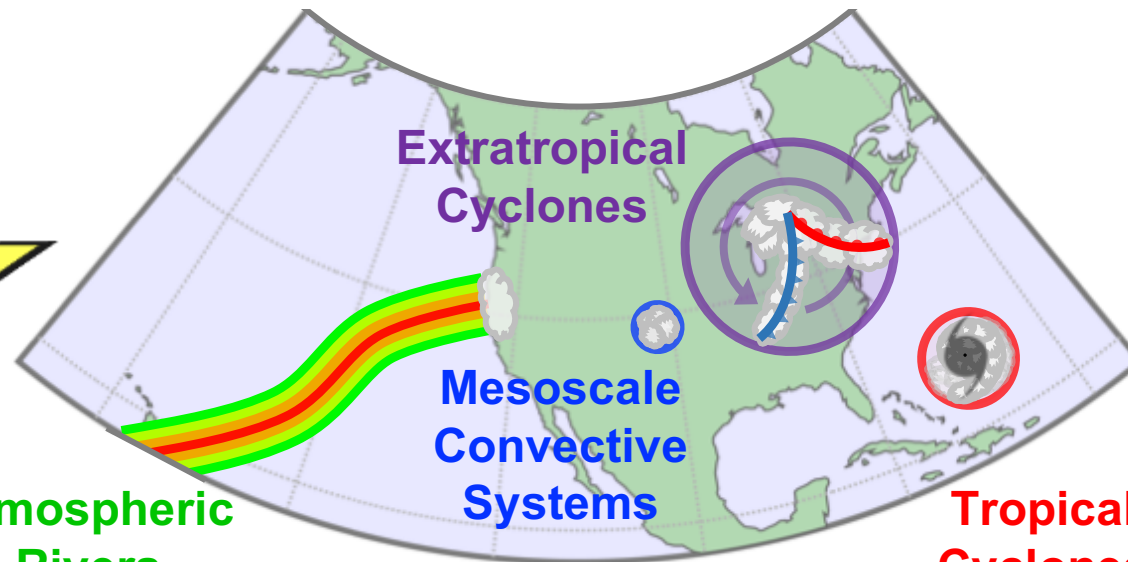
Extreme Precipitation Events in the United States

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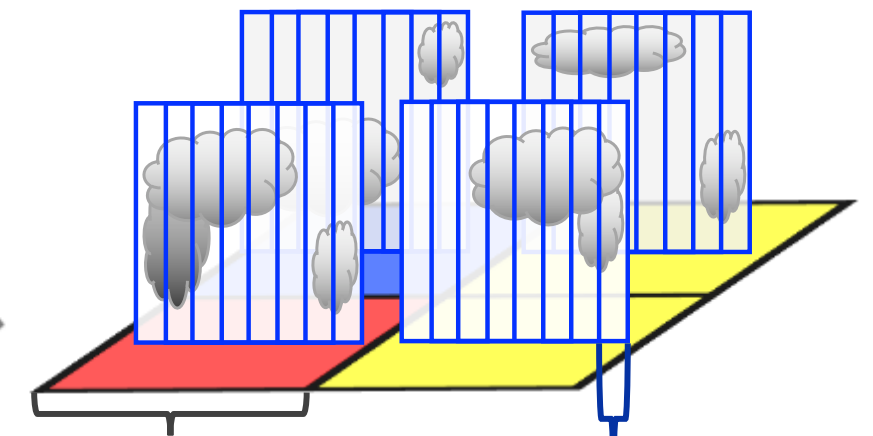


Global Resolution: 0.25°

Atmospheric
Rivers



Superparameterized E3SM



Global Resolution: 1°
Cloud Resolving Model: 2 km